Stratégies

GEO-CAPE INTELLIGENT OBSERVATION STUDIES @GSFC

http://geocape.herokuapp.com

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GEO-CAPE Workshop

September 1, 2015

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STRATEGIES OVERVIEW

Based On Current Assumptions That Need To Be Validated

Strategy 1	*Strategy 2*	*Strategy 3*	*Strategy 4*	*Strategy 5*
Ground Scheduler With Simple Priorities	Ground Scheduler With Cloud Forecast	Ground Scheduler With Sub-area Forecast	Onboard Scheduler and Onboard Cloud Detection	Smart Onboard Scheduler and onboard Image Processing to Reduce Downlink Costs
Potentially Acquired Scenes per hour				
< 10 scenes	~ 14 scenes	~16 scenes	~ 19 scenes	~ 19.2 scenes
Complexity:				
★☆☆☆☆	★☆☆☆☆	★★☆☆☆	★★★☆☆	★★★★★
Cost:				

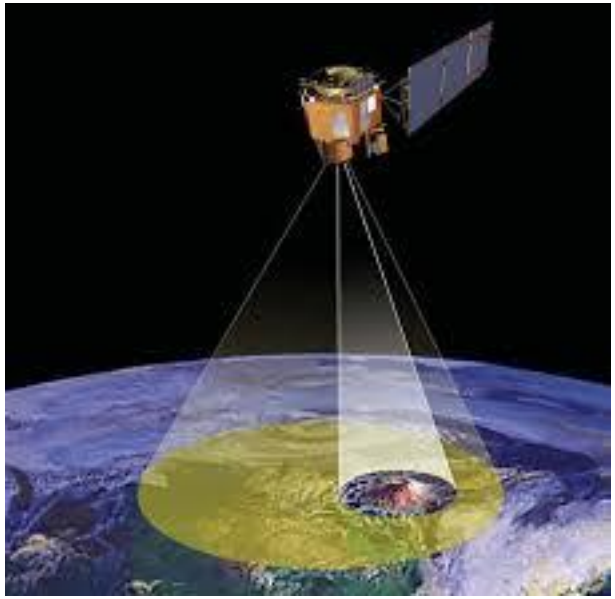
OBJECTIVES OF GSFC STUDY ELEMENTS

Analyze And Summarize Strategies To Improve Science Data Collection

Smart Cloud Forecasting

Onboard Cloud Detection

Ground/Onboard Scheduling with Robust Executive



Assumptions

+ *Mission*
+ *Instruments*
+ *Study Selection*
+ *Scheduling*

01

MISSION ASSUMPTIONS

Optimize Acquisition of "Cloud Free" Scenes At Lowest Cost

Mission Life Time: 5 years

~16 hours of Operations per day

Survey Mode

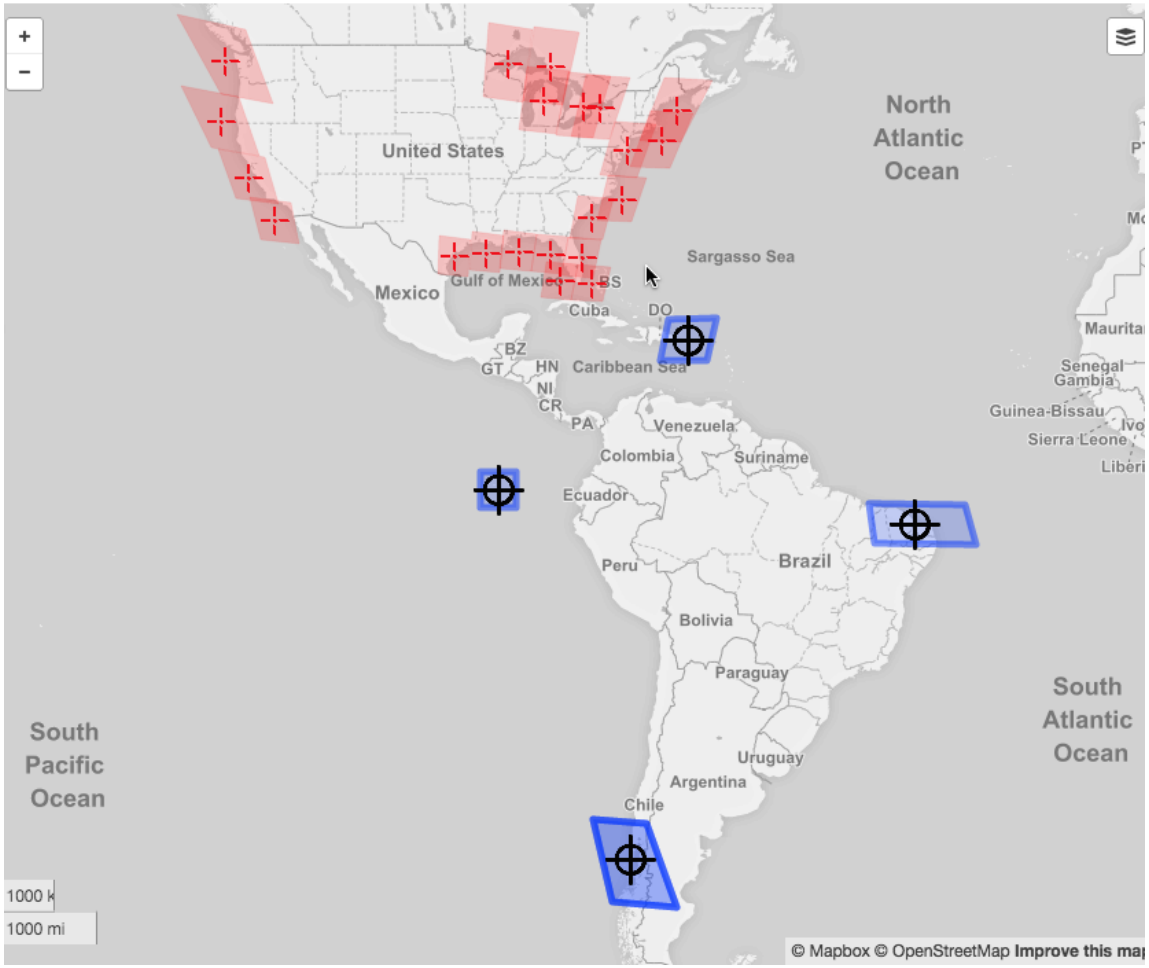
U.S Coastal Waters: East Coast, Gulf Coast, West Coast, Puerto Rico, Great Lakes

Targeted Events As Necessary

Regions of Interests

Other Coastal Waters of North & South America

Anywhere within Field of Regard



MISSION ASSUMPTIONS

Optimize Acquisition of "Cloud Free" Scenes At Lowest Cost

Standard (Threshold) Survey Mode (60min Repeat Frequency)

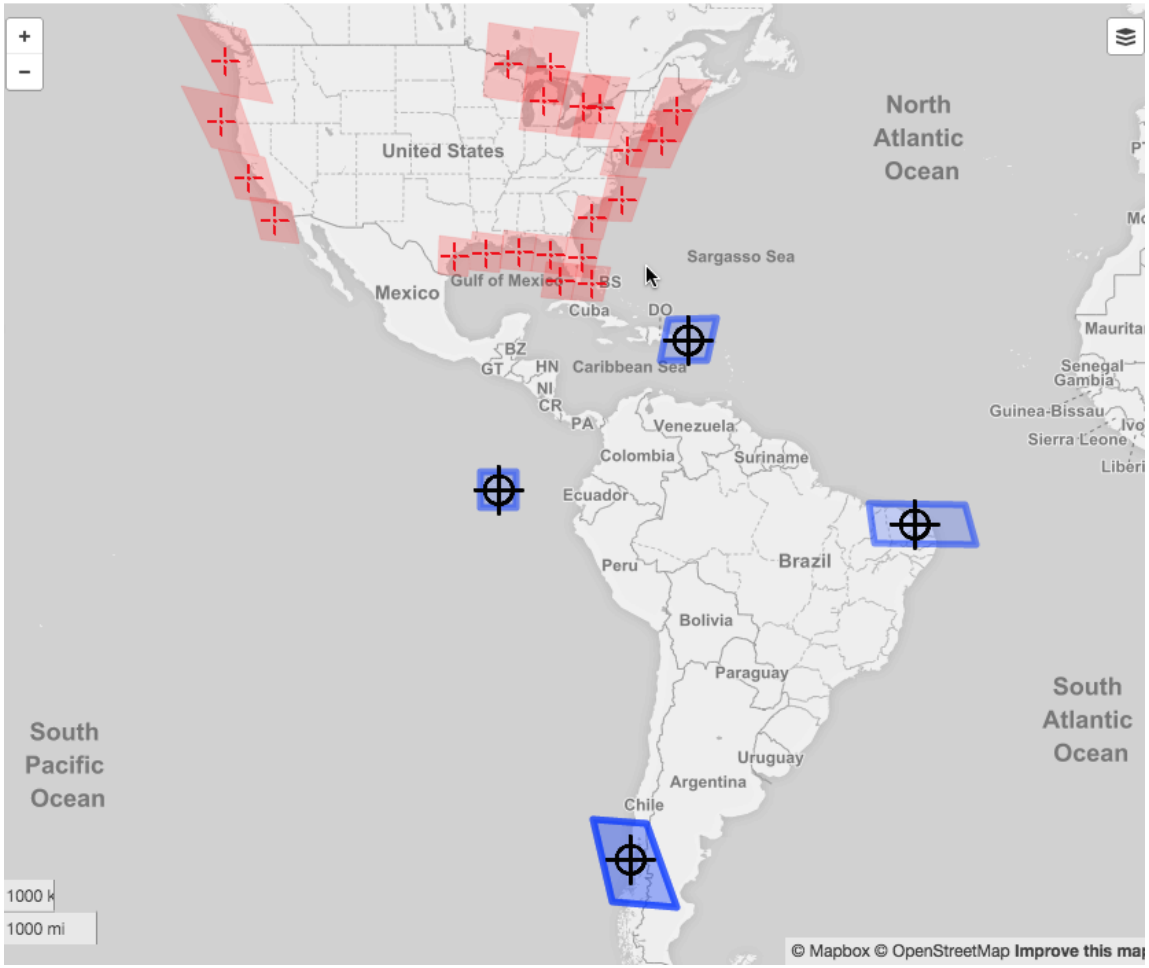
High Repeat (Baseline) Mode (30mn Repeat Frequency)

Targeted Events and Regions of Special Interest

Engineering Tasks and Special Window Events (Sun interference…)

Some scenes will be requested by external users and subject to Science Team Approval

Scenes will need some kind of a priority scheme for scheduling



INSTRUMENT CONCEPTS & CAPABILITY

Instrument Type	Filter Radiometer FR	Filter Radiometer FR	Wide Angle Spectro-meter WAS	Multi-Slit Spectro-meter COEDI	Multi-Slit Spectro-meter COEDI
Spatial Resolution (m) (nadir)	250	375	375	375	250
Spectral Resolution (nm)	5 nm	5 nm	0.4 nm	0.4 nm	0.4 nm
Spectral Range (nm) (2135 not req)	Multispectral (50) 340-1050; 1245, 1640, 2135	Multispectral (50) 340-1050; 1245, 1640, 2135	340-1050; 1245, 1640, 2135 nm	340-1050 1245,1640 nm	340-1050 1245,1640 nm
Scan Rate (km^2/min)	100,105	100,105	48,200	43,200	28,800
Mass CBE (kg)	190.4	126.3	309.4	202.8	358.6
Power CBE (W)	200.1	161.2	341.3	192.5	257.7
Volume (m x m x m)	1.5 x 1.46 x 1.02	1.0 x 0.97 x 0.68	2.6 x 1.8 x 1.5	1.5 x 1.7 x 1.1	2.2 x 2.5 x 1.7
Telemetry CBE (kbps)	15,900	10,600	23,832	23,854	35,765
Detector Size	4k X 4K	2730 X 2730	8k X 1k	2k X 1k (x 2)	3k X 1k (x 2)
Real Detector Size	4096 x 4096		Line scanner (8K)	2 line scans 2048 20 pixels apart	2 line scans 3072 20 pixels apart

THRESHOLD FR ASSUMPTIONS @375M

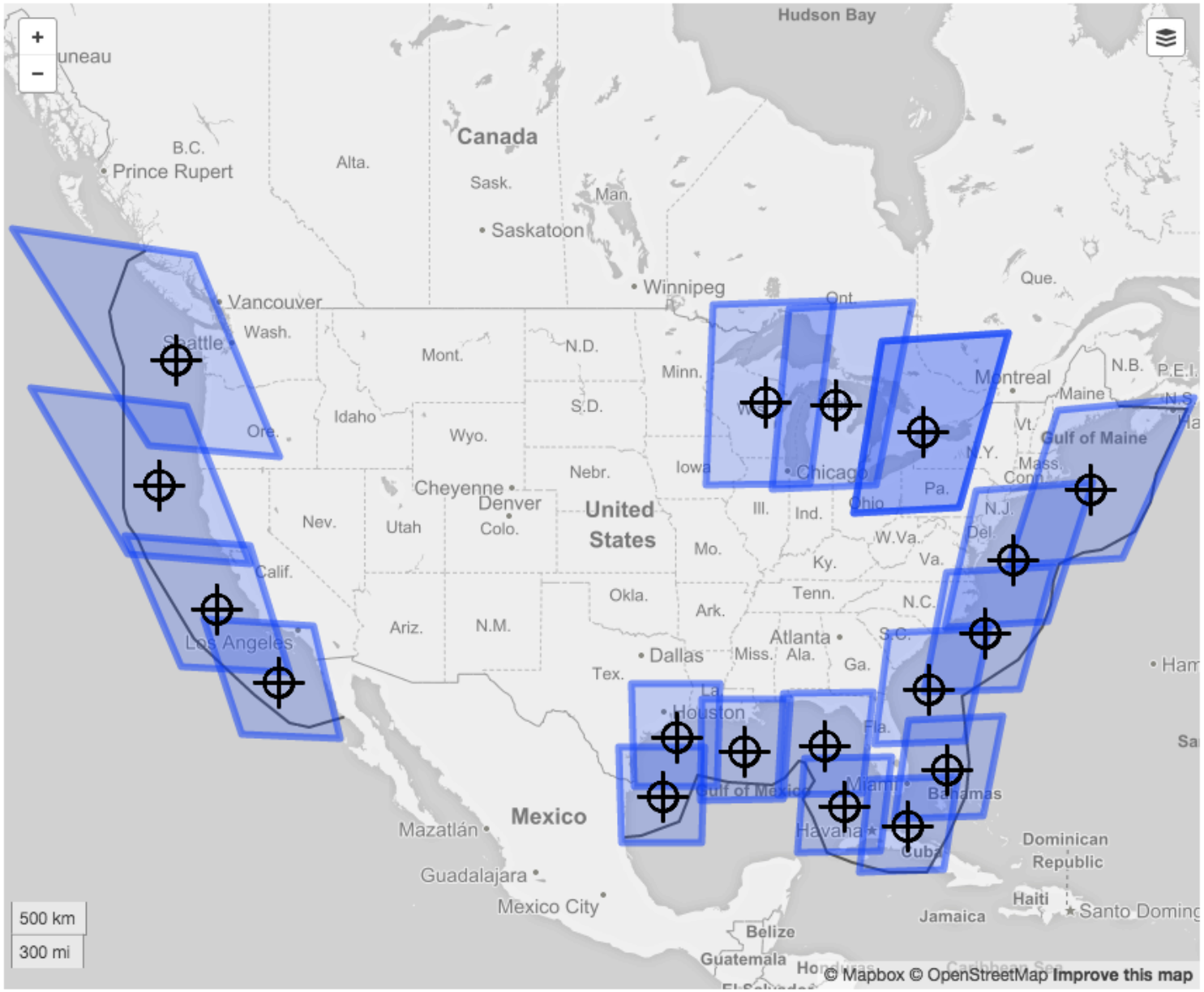
01

- *Detector Size 2730 x 2730*
- *Subsampled 2x2 – initial spatial resolution 187.5m -> 375m final*
- *Scan Rate: 100,134 km²/min -> 157 seconds per scan*
- *Scan Rate: 2730*2730*0.1875*0.1875*60/157 = 100,134 km²/min*
- *Final Scene Size: 1365 x 1365 pixels (512km x 512km)*
- *Total Time including mirror displacement = 157s + 1s = 158s*
- *50+3 bands ??? @ 2bytes/pixels*

- *Scene Size: 53*2*1365*1365 = 197.5 MB*
- *Data Ingest Rate: 197.5 / 158 = 1.250 MB/s*
- *Estimated Daily Storage/Downlink: 21 scenes/hr. * 16hr/day * 444.6MB = 65.7 GB*
- *Estimated Monthly Downlink: 1.97 TB*

Example of Instrument Analysis for each of 4 options

Strawman 18 Coastal/Lakes Survey Scenes Using FR



Source: GSFC analysis via GUI Editor, assuming spherical Earth – Satellite at 95W

INSTRUMENT ANALYSIS COMPARISON

	FR	FR	COEDI	WAS
Resolution	250m	375m	375m	375m
Scene Size	512 x 512 km	512 x 512km	768 x 535.5km	1536 x 375 km
Scene Storage	446.6MB	197.5 MB	304.15 MB	434.2 MB
High Repeat Baseline (30min)	11 scenes	11 scenes	8 scenes	2 scenes
Threshold (1hr)	22 scenes	22 scenes	17 scenes	4 scenes
CONUS Coverage	18 scenes	18 scenes	15 scenes	13 scenes
Data Rate	2.814 MB/s	1.25 MB/s	1.46 MB/s	0.57 MB/s
Parametric Cost ($M)	$132M	$108M	136.2M	165.2M
Daily Storage/Downlink	150 GB	65.7 GB	102.2 GB	145.9 GB
Monthly Downlink	4.5 TB	1.97 TB	3.1 TB	4.38 TB

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Clouds

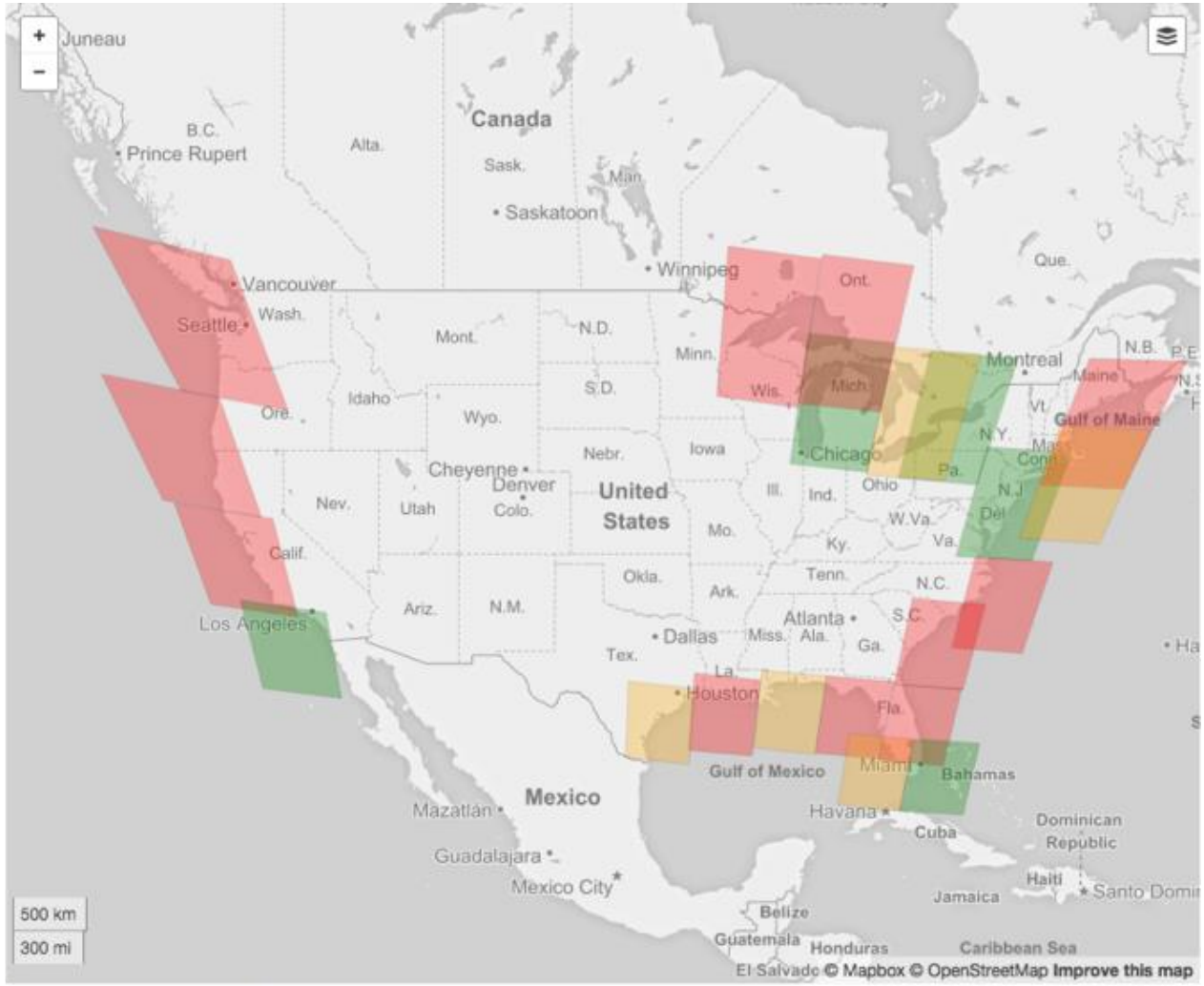
+ *Forecasting*
+ *Sub-Gridding*
+ *Cloud Detection*
+ *Onboard Detection Algorithms*

02

SURVEY SCENES & FORECAST

01

02



Red: 11 (52.4%) **Orange:** 5 (23.8%) **Green:** 5 (23.8%)

Example FR Scene Forecast Schedule

Red scenes fail cloud threshold and are not scheduled

Green scenes pass cloud threshold and are scheduled

Orange scenes are marginal and are scheduled for more evaluation onboard

CLOUD THRESHOLDING STRATEGY

01

02

Two Cloud Thresholds: Green, Orange

- Below Green Threshold: Cloud Coverage is Acceptable For Science Team, Scene is Green

- Above Orange, Scene Is Not Even Scheduled On the Ground, Scene is Red

- Between Green And Orange: Scene Can Be Scheduled, But Will Be Checked On Board. It May Become Green

This Allows Higher Threshold Values For Use by Ground Scheduler

After Acquisition, Onboard Cloud Detection Is Used To Check Scene Against Green Thresholds. Scenes Can Then Be Accepted or Rejected.

~ 20% Chance to Accept Marginal Scenes and increase Scene Marginal Return

~ 20% Chance to Reject Marginal Scenes and Optimize Data Downlink/Storage

The ~20% acceptance/rejection of marginal scenes is based on studies done for HyspIRI, GEWEX and other analysis listed in the reference backup.

GROUND CLOUD FORECAST SUB-GRIDDING

01

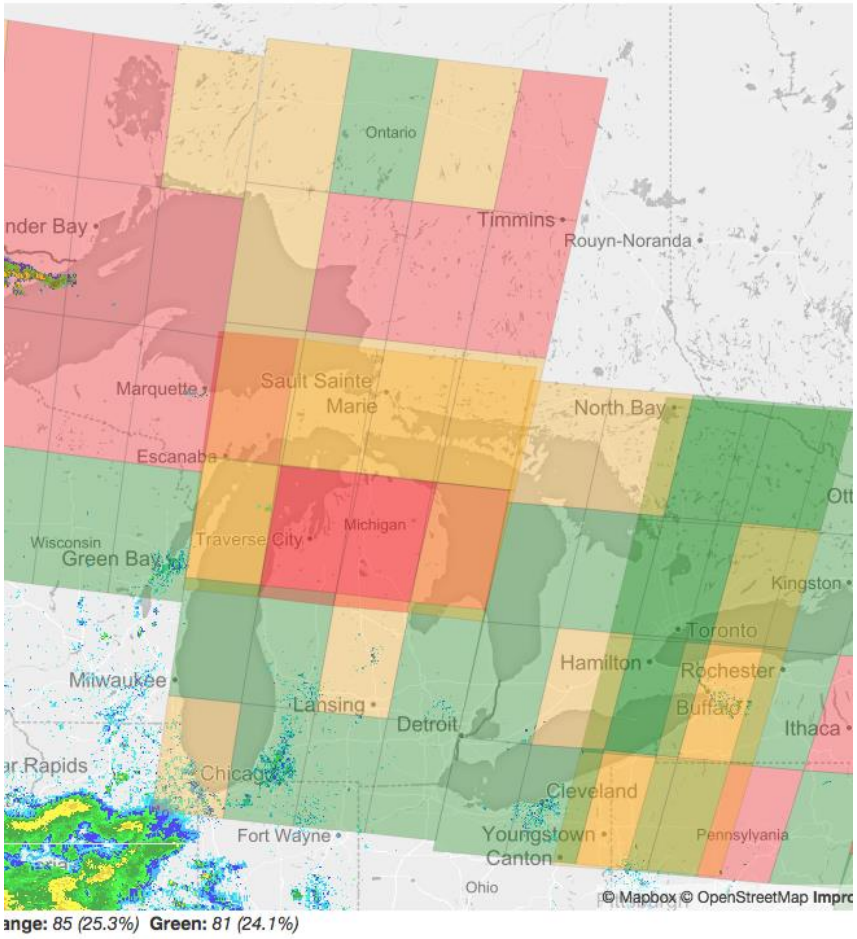
02

Cloud Forecast Optimization Strategy

Rationale: Focus Cloud Forecast on Sub-areas of the Scene (sub-grids)

Forecast is obtained at the center of sub-area of interest (and not on a pixel by pixel basis). This is faster and cheaper.

Scene Forecast is then calculated by averaging the forecasts of sub-areas.



Green: *81 (24.1%)*

ONBOARD CLOUD DETECTION

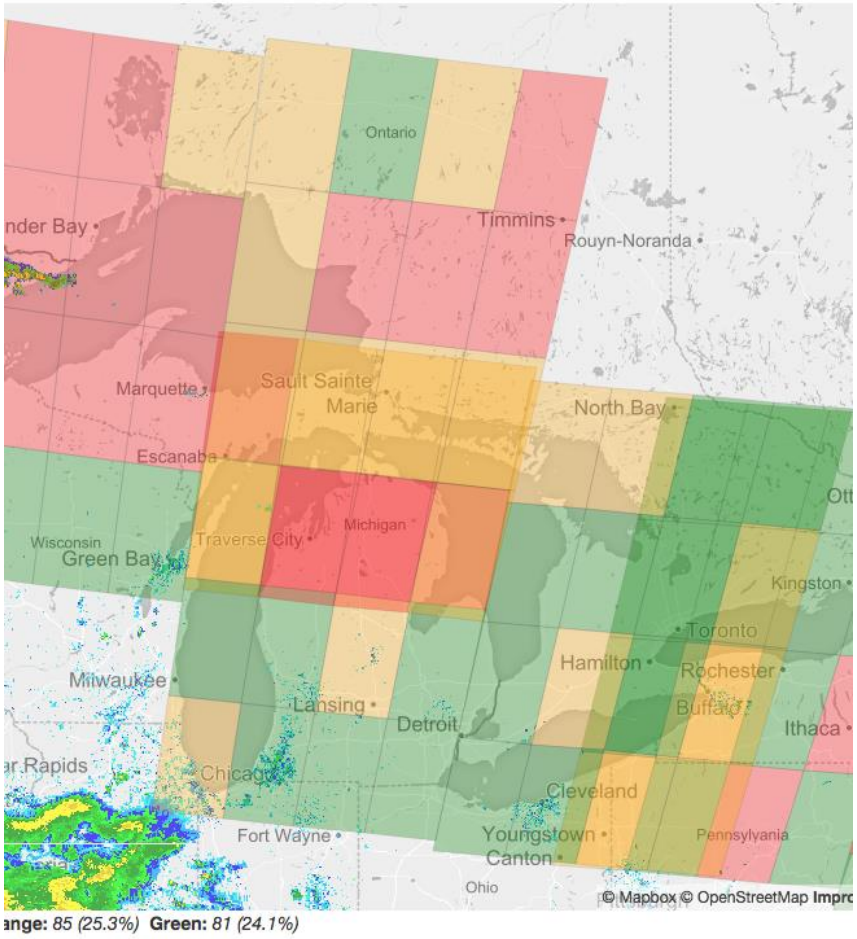
01

02

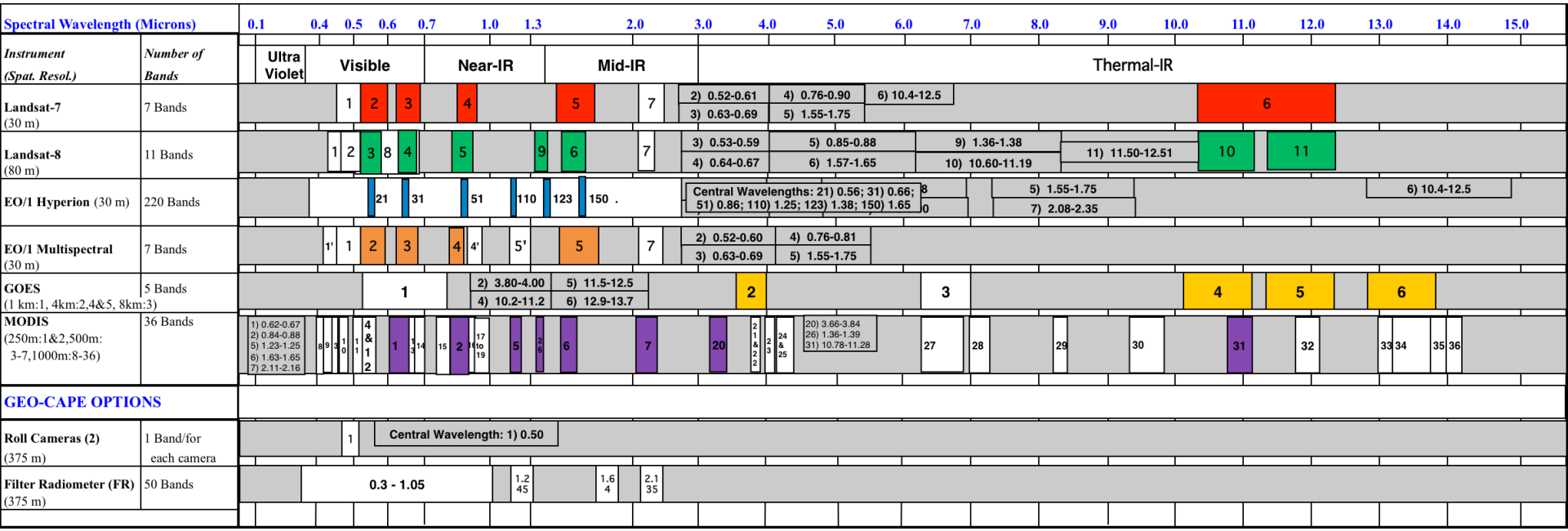
Strategy to Resolve Orange (marginal) Scenes using Scene Sub-grids

Rationale: Determine if the orange scheduled scenes were actually within the acceptable green threshold for science quality in order to make decisions about downlinking and rescheduling

Approach: Evaluate only coastal zone sub-grids (masking out sub-grids over land, for example) and average those results to determine if the green threshold is met; if successful downlink those observations; if too cloudy, delete to reduce downlink costs



SPECTRAL BANDS USED FOR CLOUD DETECTION BY OTHER SENSORS COMPARED TO THE BANDS AVAILABLE ON GEO-CAPE



Band number	Central wavelength (nm)	Bandwith (nm)	Spatial resolution (m)
1	443	20	60
2	490	65	10
3	560	35	10
4	665	30	10
5	705	15	20
6	740	15	20
7	783	20	20
8	842	115	10
8b	865	20	20
9	945	20	60
10	1380	30	60
11	1610	90	20
12	2190	180	20

Notes:

- *Thermal bands distinguish clouds from ice.*
- *SWIR band 1375nm (used by EO-1 / Landsat-8 / Sentinel 2) is the most critical to detect high cirrus clouds that contaminate scenes, especially in Coastal Areas.*

Scheduling Ops Demo

http://geocape.herokuapp.com

+ *Architecture*
+ *Strategies*
+ *KISS*
+ *Schedule Layout*
+ *Visualization*

03

USER SCENARIO TO SUBMIT NEW REQUESTS

01
02
03

- *Science team members are provided user front end GUI to add/remove scenes and edit scene attributes*
- *They enter scene parameters including location, size, priority, number of collects, cloud coverage thresholds, etc…*
- *Requests are submitted and can be accepted or rejected by the scheduling system. Every 6 hours the front end assembles the scenes to be imaged, including engineering tasks and activity blackouts, and gathers the cloud forecast for each scene*
- *The scenes are scheduled based on scene attributes and cloud forecasts. The schedule may be reviewed by the science team and potentially rejected. Scene attributes may have to be tweaked and ingested by the scheduling system to generate a new plan*
- *Approved schedule is generated and uplinked after science team approval*

SCHEDULE LAYOUT CONCEPT

01
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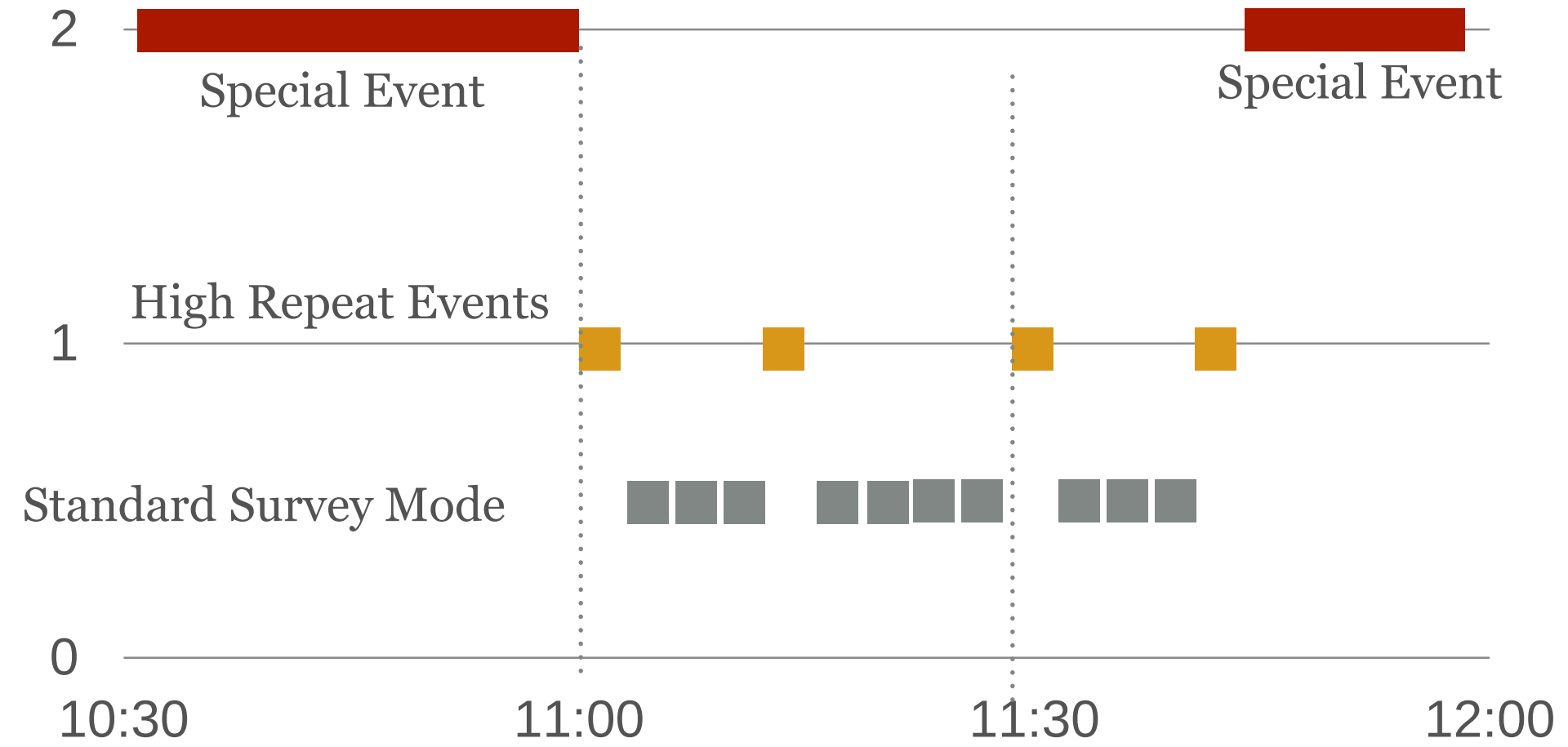
03

Priorities



SCHEDULE EXAMPLE

01
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FR Schedule

New Schedules

Date: 2015-06-15T06:00:00.000Z

Others

scene	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	24:00	0:00	1:00	2:00	3:00	4:00	5:00
scene_1	-	-	-	-	-	-	-	x	x	x	x	x	x	0.68	0.65	0.64	0.68	0.76	0.83	0.75	0.65	0.52	0.4	0.24	0.01	0	0	0	0.11	x	x
scene_2	-	-	-	-	-	-	-	x	x	x	x	x	x	0.78	0.67	0.65	0.76	0.91	0.98	0.8	0.49	0.32	0.46	0.73	0.82	0.51	0.21	0.06	0.24	x	x
scene_3	-	-	-	-	-	-	-	x	x	x	x	x	x	0.79	0.68	0.65	0.75	0.9	0.99	0.89	0.72	0.63	0.72	0.89	1	0.86	0.69	0.61	x	x	x
scene_4	-	-	-	-	-	-	-	x	x	x	x	x	x	0.9	0.74	0.65	0.73	0.88	0.98	0.88	0.73	0.65	0.74	0.9	1	0.71	0.47	0.35	x	x	x
scene_5	-	-	-	-	-	-	-	x	x	x	x	x	0.7	0.62	0.42	0.34	0.48	0.71	0.84	0.71	0.49	0.3	0.26	0.27	0.33	0.39	x	x	x	-	-
scene_6	-	-	-	-	-	-	-	x	x	x	x	x	0.36	0.27	0.13	0.08	0.27	0.6	0.81	0.76	0.64	0.62	0.7	0.87	0.98	0.86	x	x	x	-	-
scene_7	-	-	-	-	-	-	-	x	x	x	x	0.12	0.15	0.13	0.09	0.11	0.24	0.41	0.5	0.44	0.25	0.14	0.26	0.48	0.49	x	x	x	x	-	-
scene_8	-	-	-	-	-	-	-	x	x	x	x	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	x	x	x	-	-	-
scene_9	-	-	-	-	-	-	-	x	x	x	x	0.05	0.05	0.04	0.02	0.01	0	0	0	0	0	0	0	0	0	x	x	x	-	-	-
scene_10	-	-	-	-	-	-	-	x	x	x	0.23	0.44	0.54	0.49	0.31	0.16	0.13	0.14	0.14	0.14	0.13	0.12	0.12	0.12	0.01	x	x	x	-	-	-
scene_11	-	-	-	-	-	-	-	x	x	x	0.7	0.85	0.93	0.84	0.69	0.59	0.62	0.7	0.74	0.71	0.64	0.62	0.7	0.82	0.87	x	x	x	-	-	-
scene_12	-	-	-	-	-	-	-	x	x	x	0.57	0.8	0.92	0.82	0.69	0.63	0.72	0.89	0.99	0.89	0.72	0.63	0.71	0.89	1	0.85	x	x	-	-	-
scene_13	-	-	-	-	-	-	-	x	x	x	0.7	0.86	0.96	0.86	0.69	0.61	0.69	0.86	0.96	0.87	0.72	0.65	0.73	0.89	0.99	0.89	x	x	-	-	-
scene_14	-	-	-	-	-	-	-	x	x	x	x	0.65	0.65	0.64	0.63	0.65	0.76	0.91	1	0.9	0.74	0.65	0.75	0.93	0.99	0.67	x	x	x	-	-
scene_15	-	-	-	-	-	-	-	x	x	x	0.72	0.87	0.96	0.86	0.71	0.64	0.72	0.88	0.97	0.88	0.72	0.64	0.73	0.9	1	0.9	x	x	-	-	-
scene_16	-	-	-	-	-	-	-	x	x	x	x	0.84	0.91	0.79	0.62	0.52	0.52	0.58	0.63	0.62	0.61	0.61	0.69	0.79	0.78	x	x	x	-	-	-
scene_17	-	-	-	-	-	-	-	x	x	x	0.74	0.9	1	0.91	0.76	0.65	0.62	0.63	0.62	0.58	0.54	0.54	0.67	0.87	0.96	x	x	x	-	-	-
scene_18	-	-	-	-	-	-	-	x	x	x	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	x	x	-	-	-
scene_19	-	-	-	-	-	-	-	x	x	x	x	0.65	0.62	0.49	0.28	0.2	0.36	0.61	0.74	0.61	0.38	0.21	0.22	0.28	0.31	x	x	x	-	-	-
scene_20	-	-	-	-	-	-	-	x	x	0.65	0.74	0.9	1	0.9	0.74	0.65	0.74	0.92	1	0.83	0.57	0.38	0.38	0.44	0.5	x	x	x	-	-	-
scene_21	-	-	-	-	-	-	-	x	x	x	0.79	0.93	1	0.9	0.74	0.65	0.73	0.89	0.99	0.89	0.73	0.65	0.74	0.9	1	x	x	x	-	-	-
-																															
green												3	3	3	4	4	3	3	3	3	3	3	3	4	5	1	1	2	1		
orange											1	1	1	3	3	4	4	1	1	2	3	5	5	3			1		1		
red										1	7	11	13	15	14	13	14	17	17	16	15	13	13	14	16	9	2	2			
total										1	8	15	17	21	21	21	21	21	21	21	21	21	21	21	21	10	4	4	2		

-	
#Green:	52
Million sq miles:	4.47
#Orange:	39
#Red:	222
#Total:	313

Based on actual forecast data for June 15, 2015 and cloud threshold criteria per region

SCHEDULE VISUALIZATION SNAPSHOT

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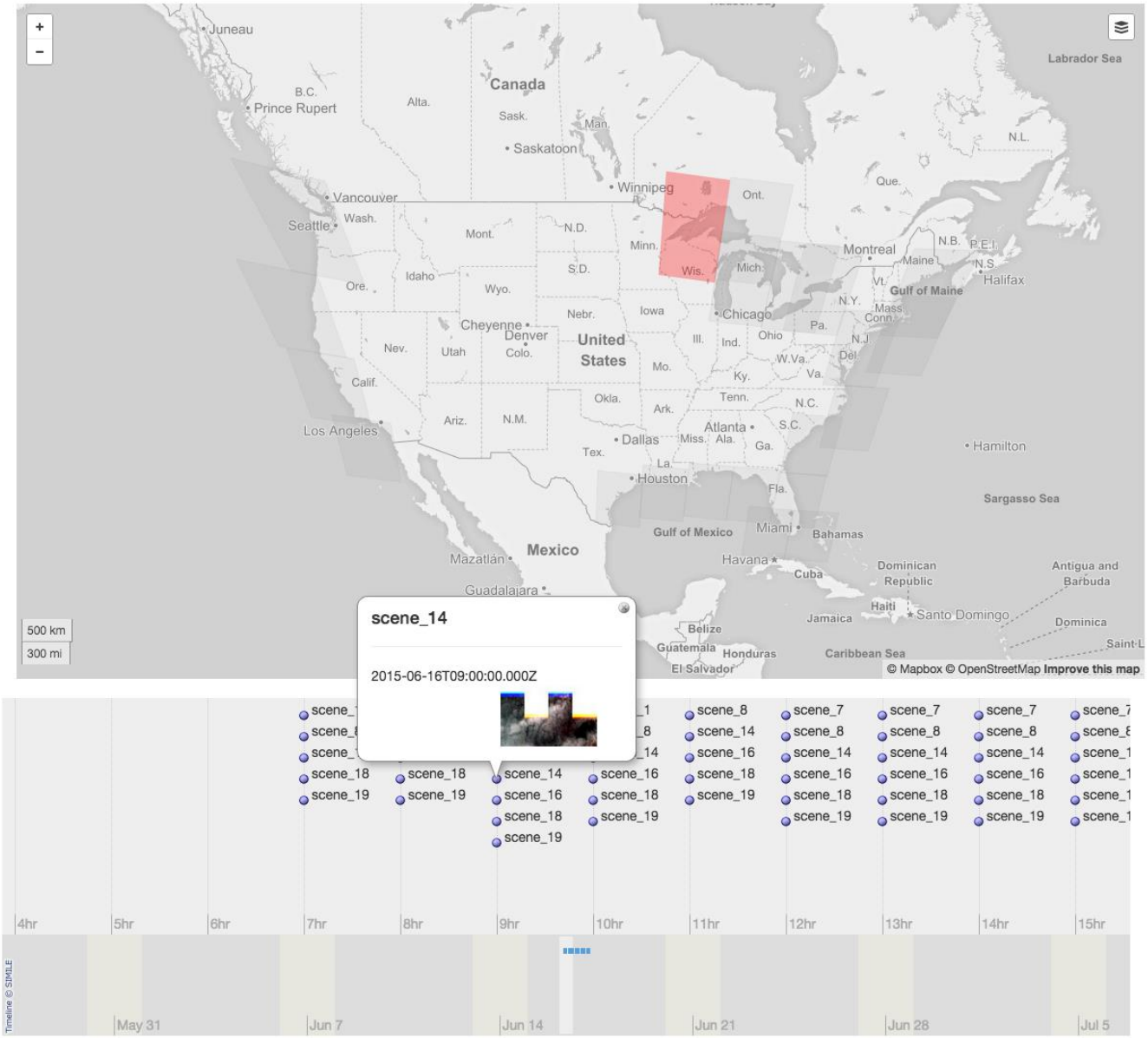

GROUND PROCESSING

01
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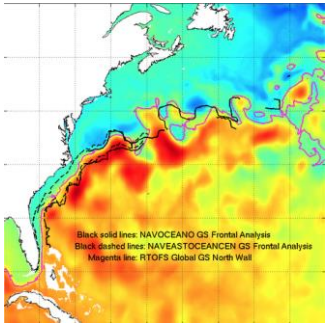
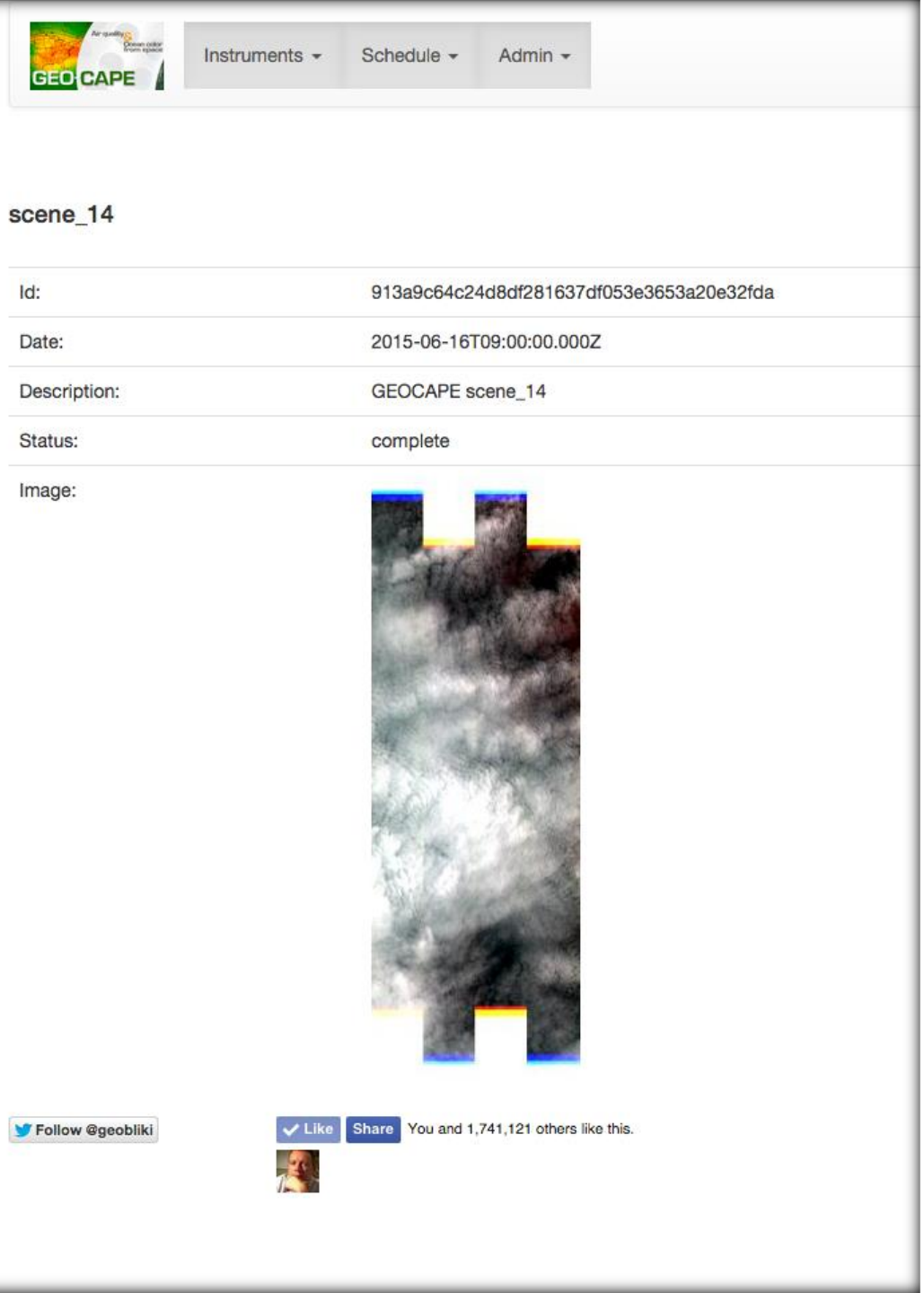
- *Calibration*
- *Atmospheric Correction*
- *Ortho-Rectification*
- *Co-Registration*
- *[Vectorization]*
- *Distribution*





BROWSE SNAPSHOT

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Full Access to Final Product(s) & MetaData

Easy To Share And Distribute to Community of Interest

Realtime User Notifications

Summary:

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Key Findings

- *GEO-CAPE Observation Operations Simulator developed*
- *Hosted Payload data handling and potential cost savings examined*
- *Candidate cloud detection algorithms identified, including value of SWIR band 1375nm*
- *Feasibility established for*
  - *Cloud threshold settings and forecast constraints, incorporating marginal scene handling*
  - *Onboard processing of cloud detection to not downlink marginal observations that fail cloud threshold (reduce data handling costs)*
  - *Cost of onboard processing capability with 2015 technology*

Use GSFC Observation Ops Simulator Tool (http://geocape.herokuapp.com)

- *Examine "What If" scenarios incorporating actual cloud forecast data for example/fixed targets*
- *Characterize instrument scene based on foot print center point to generate target observation requests*

Possible Follow-on Activities

- *Integrate scheduler with simulator to enable live simulations with dynamic targets (1-2 month)*
- *Update Simulator tool per user feedback (days to weeks)*
- *Analyze VNIR Band Study for High Cloud Detection (1-2 months)*
- *Research Commercial Vendor Communication Capabilities, Cost & API (1-2 months)*

“Now is no time to think of what you do not have. Think of what you can do with what there is.”
— Ernest Hemingway

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04

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BACKUP SLIDES

COMMERCIAL DOWNLINK COST (DOD)

This table reflects current DOD prices for Commercial Satellite Access. NASA costs have been assumed to be comparable

Current Satellite	Type	AOR	MHz	Mbps	Cost	Cost per MHz	Mbps to MHz Conversion Ratio
IS-20	Ext Ku	AFG	60	100	$200,000	$3,333	1.67
IS-17	Ku	ME Inroutes	8.1	13.5	$27,000	$3,333	1.67
IS-17	Ku	ME Outroutes	24.2	31.5	$63,000	$2,603	1.30
IS-17	C	ME - Oman	36	64	$128,000	$3,556	1.78

SATELLITE INTERNET COST (IDIRECT)

Coverage CONUS

Source: http://www.groundcontrol.com/US_Canada_Satellite_Internet.htm

750GB/month, 40 sites *$56K/month*

$0.14 per MB

CLOUD DETECTION ALGORITHMS DETAILS

LANDSAT-7 BANDS USED FOR CLOUD DETECTION

Band Number	Wavelength (Range)	Spatial Resolution (in meters)
2	0.52-0.60	30
3	0.63-0.69	30
4	0.77-0.90	30
5	1.55-1.75	30
6 (Thermal IR)	10.40-12.50	60 (30 after 02/2010)

EO-1/Hyperion Bands Used for Cloud Detection

Band Number	Wavelength (Central)	Spatial Resolution (in meters)
21	0.56	30
31	0.66	30
51	0.86	30
110	1.25	30
123	1.38	30
150	1.65	30

GOES Bands Used for Cloud Detection

Band Number	Wavelength (Range)	Spatial Resolution (in kilometers)
2	3.8 – 4.0	4 km
4	10.2 – 11.2	4 km
5	11.5 – 12.5	4 km
6	12.9 – 13.7	4 km

Landsat-8 Bands Used for Cloud Detection

Band Number	Wavelength (Range)	Spatial Resolution (in meters)
3	0.53 - 0.59	30 m
4	0.64 – 0.67	30 m
5	0.85 – 0.88	30 m
6	1.57 – 1.65	30 m
9	1.36-1.38	30 m
10	10.60 – 11.19	100 m * (30 m)
11	11.50 – 12.51	100 m * (30m)

* TIRS bands are acquired at 100 meter resolution, but are resampled to 30 meter in delivered data product.

MODIS Bands Used for Cloud Detection

Band Number	Wavelength (Central)	Spatial Resolution (in meters)
1	0.645	250 m
2	0.858	250 m
5	1.240	500 m
6	1.640	500 m
7	2.130	500 m
20	3.750	500 m
31	11.030	500 m
26	*1.375*	*500 m*

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References for Cloud Detection Algorithms: *N. Memarsadeghi, "A Review of Landsat-7 and EO-1 Cloud Detection Algorithms," on the Imagepedia section of the IMAGESEER website, https://imageseer.nasa.gov/imagepedia/Imagepedia_7_CloudDetection_Nargess_Jan2011.pdf*

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GEO-CAPE Oceans STM

Draft v.4.6 - Feb. 28, 2013

Science Focus	Science Questions	Approach (Maps to Science Question)	Measurement Requirements	Instrument Requirements	Platform Requirem.	Ancillary Data Requirem
Short-Term Processes **Land-Ocean Exchange** **Impacts of Climate Change & Human Activity** **Impacts of Airborne-Derived Fluxes** **Episodic Events & Hazards**	**1** How do short-term coastal and open ocean processes interact with and influence larger scale physical, biogeochemical and ecosystem dynamics? (OBB 1) **2** How are variations in exchanges across the land-ocean interface related to changes within the watershed, and how do such exchanges influence coastal and open ocean biogeochemistry and ecosystem dynamics? (OBB 1 & 2; CCSP 1 & 3) **3** How are the productivity and biodiversity of coastal ecosystems changing, and how do these changes relate to natural and anthropogenic forcing, including local to regional impacts of climate variability? (OBB 1, 2 & 3; CCSP 1 & 3) **4** How do airborne-derived fluxes from precipitation, fog and episodic events such as fires, dust storms & volcanoes affect the ecology and biogeochemistry of coastal and open ocean ecosystems? (OBB 1 & 2; CCSP 1) **5** How do episodic hazards, contaminant loadings, and alterations of habitats impact the biology and ecology of the coastal zone? (OBB 4)	GEO-CAPE will observe coastal regions at sufficient temporal and spatial scales to resolve near-shore processes, tides, coastal fronts, and eddies, and track carbon pools and pollutants. Two complementary operational modes will be employed: (1) survey mode for evaluation of diurnal to interannual variability of constituents, rate measurements and hazards for estuarine and continental shelf and slope regions with linkages to open-ocean processes at appropriate spatial scales, and (2) targeted, high-frequency sampling for observing episodic events including evaluating the effects of diurnal variability on upper ocean constituents, assessing the rates of biological processes and coastal hazards. (1 2 3 4 5) *Measurement objectives for both modes include:* (a) Quantify dissolved and particulate carbon pools and related rate measurements such as export production, air-sea CO2 exchange, net community production, respiration, and photochemical oxidation of dissolved organic matter. (1 2 3) (b) Quantify phytoplankton properties: biomass, pigments, functional groups (size/taxonomy/Harmful Algal Blooms (HABs)), daily primary productivity using bio-optical models, vertical migration, and chlorophyll fluorescence. (1 2 3 4 5) (c) Measure the inherent optical properties of coastal ecosystems: absorption and scattering of particles, phytoplankton and detritus, CDOM absorption. (1 2 3 4 5) (d) Estimate upper ocean particle characteristics including particle abundance and particle size distribution. (1 2 3) (e) Detect, quantify and track hazards including HABs and petroleum-derived hydrocarbons. (5) GEO-CAPE observations will be integrated with field measurements, models and other satellite data: (1) to derive coastal carbon budgets and determine whether coastal ecosystems are sources or sinks of carbon to the atmosphere, (2 3) (2) to quantify the responses of coastal ecosystems and biogeochemical cycles to river discharge, land use change, airborne-derived fluxes, hazards and climate change, and (1 2 3 4 5) (3) to enhance management decisions with improved information on the coastal ocean, such as required for Integrated Ecosystem Assessment (IEA), protection of water quality, and mitigation of harmful algal blooms, oxygen minimum zones, and ocean acidification. (3 5)	Water-leaving radiances in the near-UV, visible & NIR for separating absorbing & scattering constituents & chlorophyll fluorescence Product uncertainty TBD **Temporal Resolution:** *Targeted Events:* • Threshold: ≤1 hour • Baseline: ≤0.5 hour *Survey Coastal U.S.:* • Threshold: ≤3 hours • Baseline: ≤1 hour *Regions of Special Interest (RSI): Threshold: ≥1 RSI 3 scans/day* • Baseline: multiple RSI 3 scans/day *Other coastal and large inland bodies of water within ocean color FOR:* • Baseline: ≤3 hours **Spatial Resol. (nadir):** • Threshold: ≤375 x 375 m • Baseline: ≤250 x 250 m **Field of Regard for Ocean Color Retrievals:** 60°N to 60°S; 155°W to 35°W **Coastal Coverage*:** width from coast to ocean: • Threshold: min 375 km • Baseline: min 500 km **Scanning Priority:** •Threshold: 1. U.S. Coastal Waters* 3 to 8 times per day 2. Other coastal and large inland bodies of water 3. Open ocean waters within FOR	**Spectral Range:** Hyperspectral UV-VIS-NIR • Threshold: 345-1050 nm; 2 SWIR bands 1245 & 1640 nm • Baseline: 340-1100 nm; 3 SWIR bands 1245, 1640, 2135 nm **•Spectral Sampling & Resolution:** • Threshold: UV-Vis-NIR: ≤2 & ≤5nm; 400-450nm: ≤0.4 & ≤0.8nm (for NO_2 at spatial resolution of 750x750m at nadir); SWIR resolution: ≤20-40 nm • Baseline: UV-ViS-NIR: ≤0.25 & 0.75 nm; SWIR: ≤20-50 nm **Signal-to-Noise Ratio (SNR) at Ltyp(70˚ SZA):** • Threshold: ≥1000 for 10 nm FWHM (350-800 nm); ≥600 for 40 nm FWHM (800-900 nm); ≥300 for 40 nm FWHM (900-1050 nm); ≥250 and ≥180 for 1245 & 1640 nm (20 & 40 nm FWHM); ≥500 NO_2 band. • Baseline: ≥1500 for 10 nm (350-800 nm); NIR, SWIR and NO_2 bands same as threshold; ≥100 for the 2135nm (50nm FWHM) • Threshold: Aggregate SWIR bands to 2x2 GSD pixels to meet SNR; Baseline: No aggregation. **Scanning area per unit time:** Threshold: ≥25,000 km^2/min; Baseline: ≥50,000 km^2/min **Field of Regard:** • Full disk: 20.8° E-W and 19° N-S imaging capability from nadir for Lunar & Solar Calibrations **Non-saturating detector array(s) at Lmax** **On-board Calibration:** • Lunar: Threshold: minimum monthly; Baseline: same as threshold • Solar: Threshold: none; Baseline: daily **Polarization Sensitivity:** <1.0% **Relative Radiometric Precision:** • Threshold: ≤1% through mission lifetime • Baseline: ≤0.5% through mission lifetime **Mission lifetime:** Threshold: 3 years; Goal: 5 years	Geostationary orbit at 95W longitude to permit sub-hourly observations of coastal waters adjacent to the continental U.S., North, Central and South America Storage (up to 1 day) and download of full spatial data and spectral data.	Western hemisphere data sets from models, missions, or field observations **Measurement Requirements** (1) Ozone (2) Total water vapor (3) Surface wind velocity (4) Surface barometric pressure (5) Vicarious calibration & validation - coastal (6) Full prelaunch characterization (7) Cloud cover **Science Requirements** (1) SST (2) SSH (3) PAR (4) UV solar irradiance (5) MLD (6) Air/Sea pCO2 (7) pH (8) Ocean circulation (9) Tidal & other coastal currents (10) Aerosol deposition (11) run-off loading in coastal zone (12) Wet deposition in coastal zone (13) Wave height & surface wind speed **Validation Requirements** Conduct high frequency field measurements and modeling to validate GEO-CAPE retrievals from river mouths to beyond the edge of the continental margin.

Error (as % of nadir pixel)	**Threshol**	**Baselin**
Pointing Knowledge LOS	**<50%**	**<10%**
Pointing Accuracy LOS	**<100%**	**<25%**
Pointing Stability LOS	**<50%**	**<10%**
Geolocation Reconstr.	**<100%**	**<10%**

Intelligent Payload Module Baseline only: Near Real-Time satellite data download from other sensors (GOES, etc.) for on-board autonomous decision making.

Pre-launch characterization: Adequate to achieve the required on-orbit radiometric precision

GEO-CAPE Science Questions are traceable to NASA's OBB Advanced Planning Document (OBB) and the U.S. Carbon Cycle Science Plan (CCSP).

* Coastal coverage within field-of-view (FOV) includes major estuaries and rivers such as Chesapeake Bay, Lake Pontchartrain/Mississippi River delta and the Laurentian Great Lakes, e.g., the Chesapeake Bay coverage region would span west to east from Washington D.C. to several hundred kilometers offshore (total width of 375 km threshold).